

# A 21<sup>st</sup> century scientific perspective on Buddhism

By Minh-Không

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## Abstract

2500 years ago, things were simple, life was simple, and science was in an infant stage. Today, things are complicated, life is complicated, and science has advanced so much that reading Buddha's teachings about emptiness nature of all phenomena is incomprehensible to most people. Buddha's teachings were adapted to the understanding of the people at the time, using the language and knowledge of people at the time. Those don't seem to suit people's scientific quest for knowledge nowadays anymore. People don't believe unless things are explained in a scientific way, especially those with higher education.

This paper is an attempt to use today's science methodology to convey, in 21<sup>st</sup> century terms, Buddha's teachings especially on emptiness nature of all phenomena. Scientific model using fractal transformation for the law of universal causation commonly known as karma is introduced to explain rebirth, Buddhist's six realms of existence, enlightenment concepts and the emptiness nature of all phenomena.

## Introduction:

Today's science has advanced so much that scientists take on the roles of authorities regarding the objective, physical world [1]. However, when it comes to our minds, little is known. Scientists are troubled on how to character or analyze the mind (consciousness) using similar methodologies as they have done with the physical world. Cognitive and behavior sciences have emerged but can not explain consciousness, experiences of growing numbers of people reporting "experience after death" or the state of the minds of monks in deep meditation.

Growing numbers of conferences, symposiums and dialogs [2] between scientists and Buddhist monks have happened to bridge the gap between scientific methodologies in materialistic science and Buddhist methodologies in mind cultivating.

However, the differences between scientist's and Buddhist's approaches are deep rooted from the very foundation of science and Buddhism. This paper examines the foundations of science and Buddhism and proposes a scientific model to represent Buddhism theology.

1. "Buddhism and Science: Confrontation and collaboration", presented at International Conference on "Buddhism and Science". Central Institute of Higher Tibetan Studies, Sarnath, Varanasi by Dr. B. Alan Wallace  
<http://www.newdualism.org/papers/B.A.Wallace/Wallace-Buddhism%20and%20Science-2008.pdf>
2. 2<sup>nd</sup> Buddhism & Science symposium, July 15, 2010 in Singapore.  
The 3rd World Conference on Buddhism and Science, December 1-2, 2010 in Thailand  
Buddhism and Science: Cross road of the future, December 4-5, 2010 at Maitripa College, Portland, Oregon, USA.  
The dialogs between HH Dalai Lama and quantum physicists –  
<http://www.youtube.com/watch?v=Zjd26JSaq64>  
The dialogs between university researchers and the HH Dalai Lama –  
<http://www.youtube.com/watch?v=QyfkU8ihdAA&feature=relmfu>  
[http://www.youtube.com/watch?v=R\\_AGhAP7pzc&feature=relmfu](http://www.youtube.com/watch?v=R_AGhAP7pzc&feature=relmfu)

## Foundation for science:

In science, according to the Oxford dictionaries a postulate is “a thing suggested or assumed as true as the basis for reasoning” [3]. Therefore, a postulate is a proposition that is not proven or demonstrated but considered to be self-evident. Once you’ve accepted the postulate, other rules or laws can be deduced from these basic “foundation” and the whole science on this is formed.

For example, in Euclidian geometry, the first postulate [4] is that “you can only draw one straight which is also the shortest line between two points”. Another postulate is that “you can have one and only one plane containing any 3 arbitrary points in space”. These are fairly “obvious” to accept. This is the “Euclidian geometry” that we know and it is used in every day’s life to build geometry shapes as our house, table, chairs.

On the other hand, in the theory of relativity, Einstein’s postulate [5] is that “light is always propagated in empty space with a definite velocity  $c$  which is independent of the state of motion of the emitting body”. This is a little bit harder to be “obvious” that is if you travel at the speed of light, you still perceive light traveling at that same speed  $c$  which is approximately 300,000 kilometers per second. This is as opposed to if you travel on a car at 60 miles per hour, you would see other cars traveling along at same speed as if they were stationary. However, since the rules deduced from this postulate are able to explain phenomena observed with stellar movements and the famous  $E=mc^2$  equation deduced from this rule agrees in phenomena observed in atomic phenomena, this is accepted by scientists.

Next to postulates is a set of basic rules or laws that can not be proven but observed to be true. For example, in Newton’s dynamic mechanics, the 2<sup>nd</sup> law [6] states that the acceleration of an object asserted by an external force is proportional to the force and inversely proportional to the mass of the object ( $a = f/m$  or  $f = m \cdot a$ ). This law is observed by experiments but can not be proven (via mathematical means). Things around us – cars, machinery – are the results of applying this law.

All other laws can be proven, deduced from the postulates and those basic rules to become a science. Any theory, phenomenon that doesn’t conform to those “science laws” is deemed to be not scientific.

People used to think science is absolute, is truth. In fact, science is only relative truth, “perceived truth”. The postulates are formulated via empirical experiments or observations. The formula is then “generalized” to include all objects. Once a phenomenon is discovered that violates the postulate, another postulate is formed to cover the case and a “new” science is formed.

In science history, the Newtonian physics can not explain the observed movement of stellar bodies or atoms. Einstein’s theory of relativity is able to explain that and becomes a super-set of Newtonian physics. Einstein’s relativity physics can not explain today’s observation of sub-particle behavior. Quantum physics is realized to explain those.

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3. Oxford’s definition of “postulate” - <http://oxforddictionaries.com/definition/postulate>

4. Euclidian geometry postulates – <http://www.cliffsnotes.com/WileyCDA/CliffsReviewTopic/Postulates-and-Theorems.topicArticleId-18851,articleId-18770.html>

5. Einstein’s theory of relativity postulates - <http://home.att.net/~anti-relativity/Einstein1.htm>

6. Newton’s dynamic mechanics laws - <http://www.glenbrook.k12.il.us/GBSSCI/PHYS/CLASS/newtlaws/u2l3a.html>

## Foundation for Buddhism:

With Buddhism, to be seen as a scientific model, it is proposed that the first postulate is that “all sentient beings have the same nature and this nature is basically emptiness”. This is much harder to accept as “obvious”, most would accept this via their belief instead.

Next is a set of rules on dependent-arising phenomena [7], namely

With Ignorance as condition, Mental Formations arise  
With Mental Formations as condition, Consciousness arises  
With Consciousness as condition, Name and Form arise  
With Name & Form as condition, Sense Gates arise  
With Sense Gates as condition, Contact arises  
With Contact as condition, Feeling arises  
With Feeling as condition, Craving arises  
With Craving as condition, Clinging arises  
With Clinging as condition, Becoming arises  
With Becoming as a condition, Birth arises  
With Birth as condition, Aging and Dying arise

These are so important in Buddha teachings that Buddha himself said “Deep is this dependent co-arising, and deep its appearance. It's because of not understanding and not penetrating this Dharma that this generation is like a tangled skein, a knotted ball of string, like matted rushes and reeds, and does not go beyond transmigration, beyond the planes of deprivation, woe, and bad destinations” [8].

Last is the laws of karma i.e. “cause and consequences” of good/bad actions/behavior as the seed for subsequent actions or behavior (analogous to the “force” in Newton's 2<sup>nd</sup> rule of mechanics sense). These are disclosed in very detailed in the Patthana section of the Abhidhamma [9].

Only when you fully accept the postulate, dependent-arising rules and karma laws, then the rest of Buddha teachings would make sense. Otherwise, there would be areas where doubts arise since they don't have a solid foundation to base on.

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7. On 12 links of dependent arising –

<http://www.buddhanet.net/e-learning/depend.htm>

<http://buddhism.about.com/od/basicbuddhistteachings/tp/twelvelinks.htm>

Transcendental Dependent Arising, A Translation and Exposition of the Upanisa Sutta by Bhikkhu Bodhi –

<http://www.accesstoinsight.org/lib/authors/bodhi/wheel277.html>

8. Maha-nidana Sutta - <http://www.accesstoinsight.org/tipitaka/dn/dn.15.0.than.html>

9. The conditionality of Life - <http://www.archive.org/details/TheConditionalityOfLife>

## Scientific model for Buddhism:

In science, there is a mathematical field called fractals or cellular automation [see appendix].

Since fractal patterns are observed in nature and material-like shapes can be composed using fractal transformation, it is suggested that fractal transformation can be used to model the karma causal effect in Buddhism. However, in mathematical fractal transformations, the formula for the transformation is fixed from cycle to cycle. In this model, it is generalized so that transformation changes from cycle to cycle using dependent-arising rules and karma laws as described earlier in the foundation of Buddhism section. But since karma composes of common (collective) karma and individual karma, the transformation formula is “similar” for the most part for the collective karma but with minor “variants” for the individual karma. This is similar to where DNA of siblings is similar for the most part but there are minor variations between them. In analogy to fractal decompression process of images, one can achieve any form or formless material or beings after eons of the karma fractal transformations from a uniform “emptiness” as a starting point.

This is our scientific model of the progress of this world, our lives, and science. Each stage of mental or scientific development corresponds to a fractal detail level. But unfortunately karma so far can only be described qualitatively. It is a challenge to quantify karma using scientific tools.

We went from the “4 basic materials” – earth, water, fire, wind - to describe things we know to a molecule level than to atomic level, sub-atomic and now quantum level. It is not surprising that as we progress, science will keep finding more details, the never ending fractal details. This model explains the materialistic view of science, a perceived reality (toward more fractal details) and Buddhism mind purifying process (toward less fractal details). This model explains our lives, our thoughts, as time progresses, we’ll get more “sophisticated”, more “detailed”, more “materialistic” but farther away from our basic “true nature”, the root of all things.

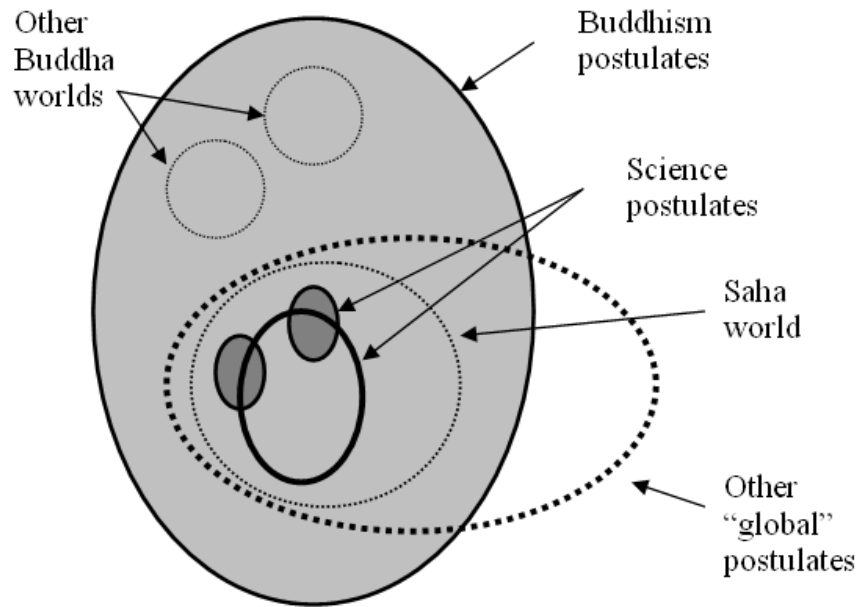
Science is moving into the “more detailed” direction whereas Buddha teachings are trying to get us to go to in “coarser level” direction i.e. severing the dependent arising cycles and unwinding the fractal cycles so that ultimately we would get closer to our “true nature” – the root, the “emptiness”.

Recently the Dalai Lama offers science community to probe/measure brain waves of highly trained monks in meditation [10]. No doubt they will find explanations in science terms the meditation process and why the stages of meditation or state of the minds progresses in such way. They would be all true, at “that scale” in the “fractal structure”. These details are more “materialistic”, “perceived details” and are farther away from the “real truth”, the “true nature of things”.

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10. Scans of Monks' Brains Show Meditation Alters Structure, Functioning -  
[http://psyphz.psych.wisc.edu/web/News/Meditation\\_Alters\\_Brain\\_WSJ\\_11-04.htm](http://psyphz.psych.wisc.edu/web/News/Meditation_Alters_Brain_WSJ_11-04.htm)

Now, the Venn diagram [11] can be used to describe the relationship of Buddhism's view and scientific views - Buddhism postulate, dependent arising rules and karma laws are denoted as the heavy circumference, all dharmas as the result are indicated as the grey area inside. Smaller circles indicate various science postulates and their internal grey areas are the resulted associated sciences – math, geometry, calculus, physics ....



Sciences that don't see the same view as that of Buddhism are likely operating under a different set of "global" postulates as indicated in the dotted line and its internal area.

From this, we can see that there are areas that are common and we all can agree and there is area where there are differences. It all depends on the "original postulates" that we base on whether they are the same or not. So, in arguing on a subject whether it is right or wrong, it is important to see whether the implied assumptions are the same. Today's science is still searching for the "global" postulates such as the big-bang theory to explain the existence of this world (note that the big-bang theory is not absolute truth, it is as valid as its postulates assume). Various sciences today are in agreement with Buddhism as in the diagram above especially quantum physics in the emptiness nature of particles and interactions among objects. Those sciences that are in agreement with Buddhism are put inside the "Buddhism circle". For example, various "science circles" are within the "saha world circle" which is the world we perceive and live in today. The global postulate circle, the big bang theory for example, encloses the saha world circle. Note that all sciences to date have 2 common postulates – space and time. The Buddhism postulates and dependent arising rules would lead to space and time concept (as explained in page 7 below). That's why "science circles" are enclosed by "Buddhism postulate circle". This diagram can also explain the existence of countless other existing Buddha worlds, Amitabha for example, besides our saha world.

Traditional “emptiness” [12] in Buddha’s teachings can be interpreted in this scientific model context. In the past, there have been discussions as what this “emptiness” really means [13]. From the Venn diagram above, you can see that since the “Buddhism circle” is outside the “our saha world circle”, there are phenomena that are beyond the grasp of our world and its science which are limited in knowledge via the “established postulates” at the time. As the result, at the time of Buddha teachings, there wasn’t any other proper word other than the word “emptiness” to explain the true nature of sentient beings. While this true nature itself is unchanged, but to better describe this true nature in today’s terms i.e. within the bounds of today’s science postulates, “pure energy life form” would be more appropriate to represent our true nature. While this still can’t convey the true nature of “emptiness” (as it would be comprehended by Buddha or any enlightened being), it would be “closer” than just “emptiness” since the science at the time of Buddha teachings, people knowledge was much more limited than what we have today.

This is similar to as using a circle in 2-dimensional geometry to describe a sphere in 3-dimensional space. Expressing this using Diamond sutra style - “the circle we are referring to is neither circle nor not circle, it is not really such, it is just called by that name” i.e. the circle is not really circle since it’s just a name to describe the sphere which is inconceivable in 2-dimensional terms.

This is an analogy to a similar verse in the Diamond sutra - “And Buddha answered: Subhuti, those to whom you refer are neither living beings nor not-living beings. Wherefore? Because “living beings”, Subhuti, these “living beings” are not really such; they are just called by that name.” [14]

Why is “emptiness” being energy ? First refer back to the Heart sutra:

“The characteristics of the voidness of all dharma are non-arising, non-ceasing, non-defiled, non-pure, non-increasing, non-decreasing” [15]

In today’s words, this refers to the “law of conservation of energy” – energy can not be created nor destroyed (non-arising, non-ceasing). Second, this also refers to, according to the 2<sup>nd</sup> law of thermodynamics, an energy body in perfect equilibrium where its entropy [16] is at maximum i.e. perfectly uniformed (non-defiled, non-pure, non-increasing, non-decreasing).

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12. On Buddhism emptiness - <http://www.thebigview.com/buddhism/emptiness.html>

Emptiness - Cula-suññata Sutta <http://www.accesstoinsight.org/tipitaka/mn/mn.121.than.html>

13. The Essence of Other-Emptiness, by Taranatha, translated and annotated by Jeffrey Hopkins  
Snow Lion Publications, 2007

14. Diamond Cutter Sutra (vajra prajna paramita sutra) Published by the DaeJang Gyong Research Institute of Haein-sa Monastery, Korea, p-12.

15. Prajna Paramita Heart sutra by translated by Tripitaka Master Hsuan Tsang, commentary by Grand Master T’an Hsu ,  
English translation by Ven. Master Lok. <http://www.buddhanet.net/e-learning/heartstr.htm>

16. Entropy is an indication or measurement of how well a “system” is distributed uniformly. For example, a glass of water and ice would have smaller entropy than that when the ice is melted (more uniformed). The 2<sup>nd</sup> rule of thermo-dynamics states that for an isolated system, the entropy of the system can only be the same or increasing i.e. can not decrease. For example, a drop of ink in a glass of water would tend to spread to get the ink dissolved evenly in the water i.e. more uniformed. Any machine, device such as “perpetual motor” that would decrease the entropy of an isolated system is scientifically impossible.



If applying Einstein's famous equation  $E=MC^2$  that describes the transformation between energy and matter, one can easily see why in the Heart sutra - "All things are marked by emptiness" where "emptiness" is energy as the interpretation above. Note also that energy in its pure form has never realized in today's science. We always perceive energy in forms like heat, light, electricity, gravity, motions, chemical bonds ...

This "energy body" is not similar as "passive" energy we know in today's science but this energy body is a "life form with ultimate wisdom". Keep in mind that this is the "perceived emptiness" within the bounds of current science, the mapping of "true emptiness" into today's "scientific systems".

Now, starting from "emptiness", if for some reason, this "emptiness" is "shifted" i.e. not in perfect distribution state any more, "ignorance" i.e. not knowing the truth would result in a "mental formation" that there is some part of this "emptiness" is "different" than "other part" of this emptiness. The consciousness of "self" and "non-self" is formed (and also the consciousness of space). Once the consciousness of "self" and "non-self" is formed, there would be a consciousness of the "boundary" of the "self" and the "non-self" i.e. form is realized. Once the "form" is realized, at this boundary, there would develop a "sense" consciousness to be able to "feel" the other side and eventually a sense organ is formed (consciousness of changes leads to consciousness of time). If the rules of dependent-arising and karma keep applied, it would end up with the first simplest "living beings" whether they are viruses or micro-organisms. Imagine the rules of karma and these fractal dependent arising cycles keep going for eons, what we have is our world, our societies, our science as we know today. Note also that this example doesn't imply the "first cause" i.e. how this universe if formed. The explanation is still within the bound of today's science to clarify the 12 dependent-arising phenomena.

Fractal transformation has been used for image compression. In fractal image de-compression [17], one starts from a uniform gray sheet and the fractal decompression formula is applied over and over to restore original object. Similarly, one can start from pure uniformed energy to end up with a real objects or beings after eons of fractal transformations of dependent arising cycles and karma laws.



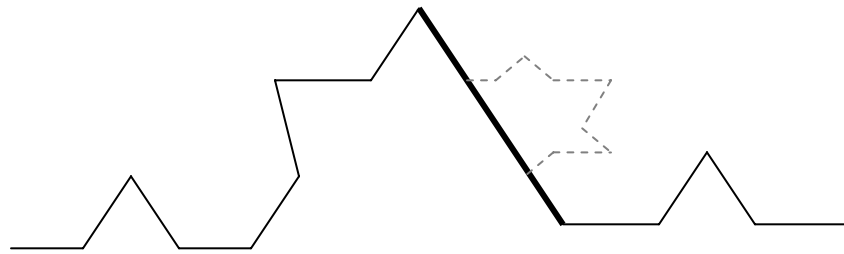
On the other hand, if all materials in this universe transform into pure energy and the energy is distributed perfectly evenly i.e. at maximum entropy state, it would become "one", "no-self" because of the uniformness; no part could be differentiated from "other part". The time concept would cease since the state of this uniform energy stays unchanged, there is nothing to "mark" the past, present or future. Space concept would also cease since there is nothing to mark "here" and "there". Keep in mind that this interpretation is still bound by the limit of today's science. As science progresses in the future, the science's postulates are "enlarged" to be a superset of today's science, the "perceived emptiness" and "fractal transformation of karma laws" would (or should) be then re-modeled to be closer to the "real truth".

17. Fractal image compression, AK Peters, Ltd. by Michael F. Barnsley & Lyman P. Hurd  
Fractal decompression sample -  
[http://www.cs.northwestern.edu/~agupta/projects/image\\_processing/web/FractalImageCompression](http://www.cs.northwestern.edu/~agupta/projects/image_processing/web/FractalImageCompression)

To further verify this fractal model against Buddha's teachings, from the Diamond sutra:

"Yet when vast, uncountable, immeasurable numbers of beings have thus been liberated, verily no being has been liberated" [18]

That can be visualized symbolically as described by a fractal structure below. If each sentient being is represented as a "detail" on a Von Kock fractal structure [19]. When a bodhisattva helps to liberate many sentient beings as symbolically depicted in the heavy line below, none was liberated (sentient beings that were liberated are all the detail levels from that heavy line if the fractal transformation were applied from that level).



Through this, we can see that when all sentient beings are "liberated" (i.e. getting to the "root"), "no sentient being was liberated" and the end result is a unified "one", "no-self", the "emptiness".

This example is fairly simplistic to convey the idea. The actual dependent-arising rules according to the karma of each sentient being and the complex network of inter-karma of beings, when applied, sentient beings would move toward or away from the "root" depends on their good/bad karma in the past (lives). The world would move away or toward the root also depends on the collective karma [20]. The quantum physics view of interaction among particles or objects is very similar to this inter-karma among sentient beings.

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18. Diamond Cutter Sutra, published by the DaeJang Gyong Research Institute of Haein-sa Monastery, Korea, p-1.

19. Fractal Von Kock's curve - <http://www.jimloy.com/fractals/koch.htm>

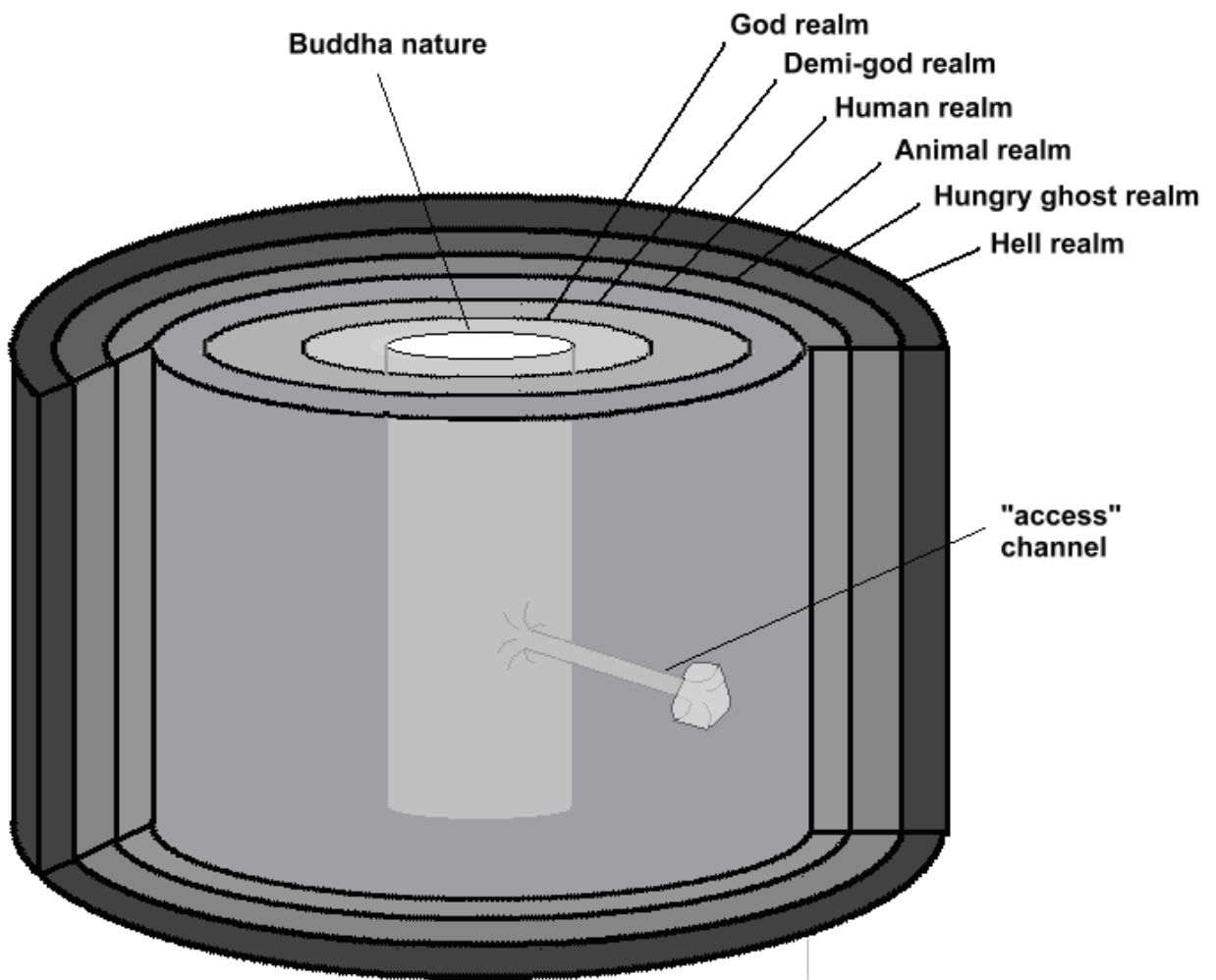
20. Cakkavattisihanada Sutta - <http://www.basicbuddhism.org/index.cfm?GPID=29>



In Buddhism, sentient beings are born according to past karma into each of the 6 basic realms— god, demi-god (asuras), human, animal, hungry ghosts or hell realms [21].

The picture below is to symbolically depict how the 6 realms of existence in Buddhism are perceived from this scientific model.

At the center core is our “Buddha nature”.  
The 1<sup>st</sup> cylinder layer is the god realm where their karma is “very light”.  
The 2<sup>nd</sup> cylinder layer is the demi-god realm where their karma is “thicker” then that of the god realm.  
The 3<sup>rd</sup> cylinder layer is the human realm  
The 4<sup>th</sup> cylinder is the animal realm where their karma is worse than that of human’s.  
The 5<sup>th</sup> cylinder is the hungry ghost realm where their karma is worse than that of animal’s.  
The 6<sup>th</sup> cylinder is the hell realm where their karma is worst.



21. Six realms of existence in Buddhism –

<http://buddhism.about.com/od/basicbuddhistteachings/tp/Six-Realms-of-Existence.htm>

The karma can be visualized as a cloud covering and hindering our Buddha nature to see things the way they really are. This “karma shield” causes us to perceive things (including our present forms) according to the realms we are in whether we are a god, a human or an animal ... The “thicker the shield”, the “farther” we are from our true nature. We perceive life starting and ending as this karma shield changes its state according to our past karma. That’s how we “die” from one realm and “reborn” to the other realm or reborn in the same realm. When one reaches enlightenment, all these “karma shields” are shredded, one returns to his/her true nature.

This gives insight to the re-birth process that most westerners find it’s hard to believe.

Buddha taught various dharmmas according to the past karma of each person. Therefore, there are recorded teachings in various levels. Unfortunately, that makes it difficult for us to know where to start and where to go next. The best is to try everything first, once you see a pattern on a particular sutra or methods easy to understand or feel more “suitable” to you. Then try to go deeper in to that line of sutras or method in more depth and details.

Various dharma practices such as zen, chanting, pure-land and tantras are methods to effectively sever the dependent-arising cycle. This effectively opens a “channel” through these “karma shields” to gain access to our Buddha nature. That is why when this channel is open, people often feel a vast tranquility upon reaching Samadhi state (concentration or absorption state of mind). This access allows us to “see” things “better”, to understand the “Buddha teachings” better via our own Buddha nature. Doing it frequently, it’s like a “boot-strap” process with positive feedback. It makes it easier “next time” we try to open this channel again since we are “wiser”, we understand Buddha teachings better which in turn helps the next time. People meditating, who frequently open this “channel”, can keep the duration of the channel longer and/or “widen” channel. This explains why some sages have gained the “god/divine eye” (“eye” that can see through material objects, can see sentient beings in other existence), the “wisdom eye” (“eye” that can see the true nature of things) and/or the “dharma eye” (“eye” that understands all dharmas, can see karma in the past and lives in the future as the result of past karma) as they are able to easily access their Buddha nature that has the ultimate wisdom [In contrast, today’s science can not predict exactly an outcome of throwing a dice since all the factors affecting its movement are too numerous to be accounted for. Only a few primary factors are included within computing power means to calculate the probability of the dice landing position].

That’s why (be able to access to the Buddha nature) Nagarjuna was able to comprehend the “real emptiness” in his analysis of emptiness [22]. That’s why Vimalakirti comprehends the “inconceivable liberation” ability of Bodhisattvas [23]. Describing these using the words at the time are mostly difficult to comprehend and are often being disregarded by today’s science.

If the positive feedback is strong enough, it causes an avalanche effect and all the “karma shields” are shredded, one achieves enlightenment.

When a person dies or has near-death experience, there is a brief moment he/she has access to the Buddha nature when the “karma shield” is transformed. This explains how they could see their past lives and karma. For experienced dharma practitioner, this gives him/her an opportunity to escape the birth/death cycle [24].

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22. Causality & emptiness, The Wisdom of Nagarjuna - [http://www.buddhanet.net/pdf\\_file/nagarjuna.pdf](http://www.buddhanet.net/pdf_file/nagarjuna.pdf)

23. Vimalakirti Nirdeśa Sutra - [http://www.fodian.net/world/0475\\_06.html](http://www.fodian.net/world/0475_06.html)

24. About Bardo - <http://buddhism.about.com/od/vajrayanabuddhism/a/bardothodol.htm>

## Conclusion

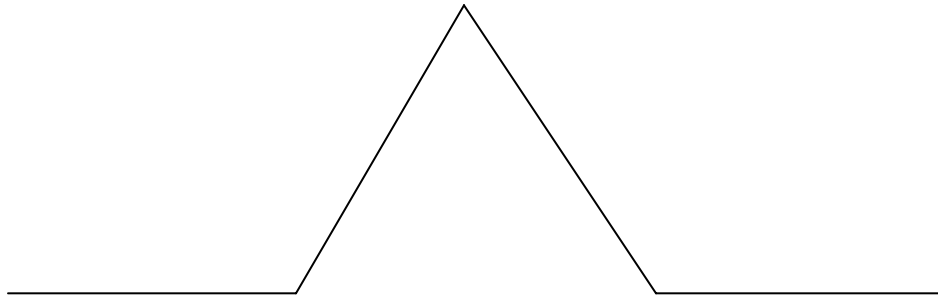
The foundation of Buddhism has been analyzed using scientific approach of postulates and basic laws. Venn diagram has been used to represent the Buddha dharma in relation with other sciences. Fractal transformation has also been used coupled with those postulate and karma laws to represent the form and formless formation of materials and sentient beings as seen in Buddhism theology. It also gives insight to rebirth concept, the Buddhist's six realms of existence as well as enlightenment concept. This scientific model is also verified against traditional Buddhist scriptures.

We hope that these would give those with scientific mind a good solid foundation to spark their belief in Buddhism and those who are already on the path something to re-assure their belief in this scientific world. In reality, this world and our perceptions seem very real to us, we have to deal with them the best we can to reduce our bad karma. In practice, just like science, one doesn't dwell into details of the basic formulas for quantum physics or classical Newtonian physics to believe in every day's phenomenon as how a car, a boat or a space vehicle works. In Buddhism, one would use the 8-fold path as the general compass to make sure the direction taken is, in general, correct. The teachings, stories, advises in the Tripitaka as well as analysis, explanations by dharma masters would provide more details and examples suited to each person's level, depending on where he/she is on "the path".

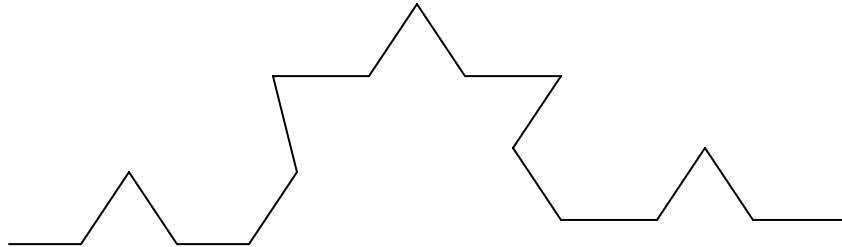
To conclude, "If there is any religion that would cope with modern scientific needs it would be Buddhism" which is believed to be a quote from Einstein.

## Appendix - Fractals

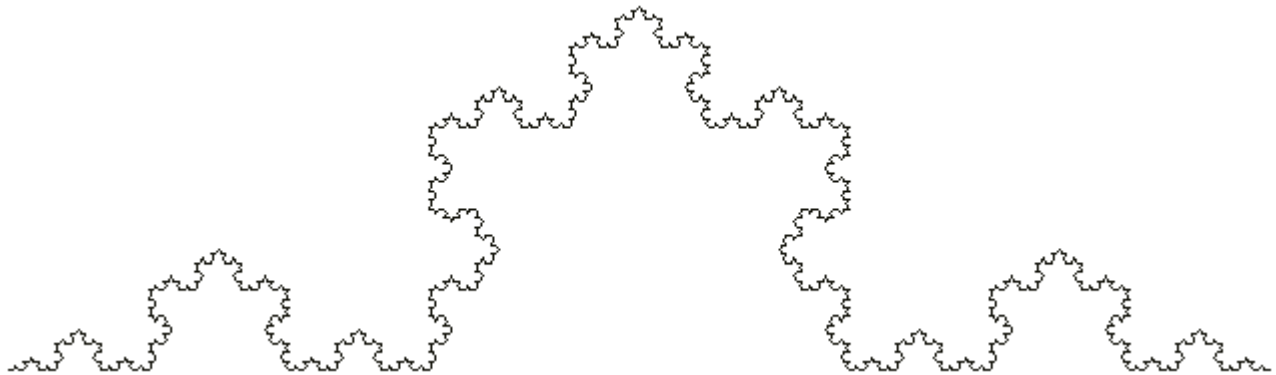
In fractals, if the same rule, formula, or algorithm is applied over and over again, it results in an interesting outcome. For example, if the “rule” is to make a “mountain” in a middle of the line segment (Von Kock curve [19])



Now apply the same rule on the new line segments



If this rule is applied over and over again, the figure would tend to “converge” to some shape called “conjecture” of this “rule”. Here is the 5<sup>th</sup> order Von Kock curve



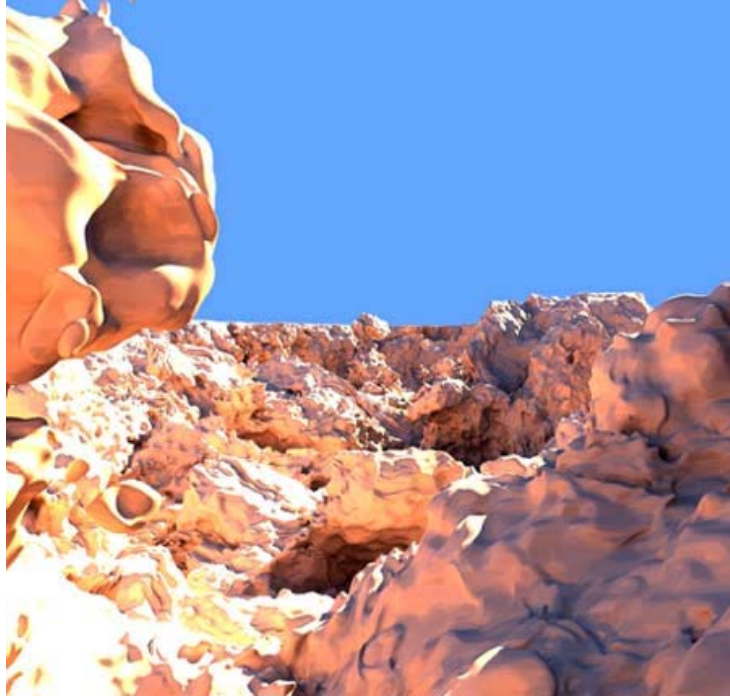
These fractals have been recognized in natural shapes [25], for example a “fractal fern”.



Another example is Romanesco (a cross between broccoli and Cauliflower, which accentuates the great fractal spiral patterns on the top)



Or it could be totally synthesized with pure mathematic equations as in this Iterative Desert Landscape: this windswept landscape, looking a bit like sandstone is completely generated by math/fractal equations



DNA structure and its passing from parents to children is another example of a fairly complicated iterative structure in nature.

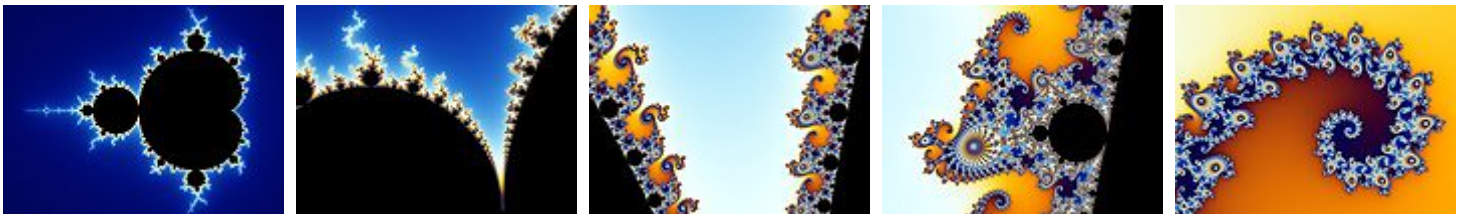


An amazing characteristic of fractals is that at any “coarser” level, one can always go to a deeper “detailed” level and find more details which is often referred as “artificial details” as in the well known Mandelbrot set [26].

Excerpts from [http://en.wikipedia.org/wiki/Mandelbrot\\_set](http://en.wikipedia.org/wiki/Mandelbrot_set):

The Mandelbrot set shows more intricate detail the closer one looks or magnifies the image, usually called "zooming in". The following example of an image sequence zooming to a selected  $c$  value gives an impression of the infinite richness of different geometrical structures, and explains some of their typical rules.

The magnification of the last image relative to the first one is about 10,000,000,000 to 1. Relating to an ordinary monitor, it represents a section of a Mandelbrot set with a diameter of 4 million kilometers. Its border would show an inconceivable number of different fractal structures.



Start

Step 1

Step 2

Step 3

Step 4



Step 5

Step 6

Step 7

Step 8

Step 9



Step 10

Step 11

Step 12

Step 13

Step 14

26. Mandelbrot fractal and artificial details - [http://en.wikipedia.org/wiki/Mandelbrot\\_set](http://en.wikipedia.org/wiki/Mandelbrot_set)